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The Effect of Successive Interpolations on Retroactive and Proactive Inhibition

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THE EFFECT OF SUCCESSIVE INTERPOLATIONS ON RETROACTIVE AND PROACTIVE INHIBITION

CHAPTER I

EXPERIMENTAL AND THEORETICAL BACKGROUNDS OF THE PROBLEMS

A. INTRODUCTION

THIS MONOGRAPH is a report of three separate but closely related experiments, two dealing with retroactive inhibition and one with proactive inhibition. Each experiment was designed to yield independent data within itself and at the same time allow for direct comparison with the others. Specifically, the first experiment was set up to determine what influence the learning of *several* successive lists of paired associates would have on the retention of an originally learned list (retroactive inhibition); the second experiment was designed to establish a relationship between varying degrees of learning of a *single* list and the retention of an originally learned list (retroactive inhibition); and the third experiment proposed to discover the decremental effects on retention resulting from the *prior* learning of several lists (proactive inhibition).

Aside from the systematic data to be derived from each of these three experiments, all have a bearing on certain theoretical issues relative to retroactive and proactive inhibition. These issues will be considered in a later section of this chapter.

As usually defined, retroactive inhibition (RI) refers to the decrement suffered in the retention of an activity as a consequence of other activity intervening between original learning and the retention test. If the term "retroactive" is divorced from its causal connotation, little confusion results from its use. The concept "proactive inhibition," on the other hand, has been subject to considerable misunderstanding in recent years, primarily because the term has been applied to two analogous phenomena differentiated by the operations used to measure them but not differentiated in any theoretical sense. Some verbal distinction of the two can be obtained by designating one as "proactive inhibition in learning" and the other as "proactive inhibition in retention." Proactive inhibition in learning refers to a retardation in the *learning* of an activity as a result of having engaged in prior activity. Proactive inhibition in retention denotes the decrement suffered in the *recall* of an activity as a result of the prior learning of another activity.

The greatest drawback to the employment of such terminology for these proactive effects lies in the cumbersome character of the writing which necessarily results. In an effort to avoid this awkwardness and at the same time retain a distinction between the two types of proactive inhibition, a somewhat different system will be employed. In this monograph proactive inhibition in learning will be called *associative inhibition,* and proactive inhibition of recall will be designated as *proactive inhibition* (PI).

B. EXPERIMENTAL BACKGROUND OF THE PROBLEMS

Since the turn of the century, a great number of experiments have been performed dealing with RI. It has been recognized (7, 9) that the operations

defining RI constitute the major and perhaps fundamental cause of all forgetting. Many of the "laws" of RI as determined in classical learning experiments have received subsequent verification in the classroom and definite steps have been taken to utilize this knowledge in curricula construction and other pedagogical procedures (15). But, although most of the important variables influencing RI appear to be recognized, a knowledge of the *interaction* of these variables is decidedly lacking. Too much experimentation has been haphazard with little thought to the importance of systematic research. Isolated hypotheses have been tested with little opportunity to incorporate the results into a systematic body of knowledge. The long series of studies conducted by McGeoch and his associates (9) is a notable exception. It appears that the fundamental problem of research on RI still remains that of an orderly study of all effective variables for representative classes of materials and activities. From such experimentation laws involving a single variable can be derived with a far better opportunity to work out the laws governing the interaction or compounding of variables. Such a procedure also allows for the development of a theoretical system in which the data can be ordered.

The present studies have concentrated on paired-associates learning in which the interpolated material is varied in two ways: (1) in experiment A the variation is in terms of the number of different lists learned, usually called the amount of interpolated activity, and (2) in experiment B, the variation has been in terms of the number of trials on a single interpolated list. The pertinent experimental literature will be considered first for experiment A.[1]

RI as a Function of the Number of Interpolated Lists

There is only one reported experimental study dealing with RI as a function of the number of interpolated lists. This study by Twining (17) used serial lists of eight nonsense syllables each. The original list was always learned to a criterion of one perfect trial after which 1, 2, 3, 4, or 5 lists were learned for 10 trials each. Five groups of subjects were used, one for each variation in the number of interpolated lists. Two experiments were performed, one in which the time between original learning and recall was held constant at 30 min., and the other in which time was increased concomitantly with the increase in the number of interpolated lists. The differences in the results of the two experiments were so small it is apparent that the fundamental variable was the number of interpolated lists and not the minimum activities which occurred during the lengthened rest periods of the second experiment.

Twining found that with an increase in the number of interpolated lists there was a parallel increase in the amount of RI. This was true whether the inhibition was measured in recall scores or by a relearning criterion. The curves for recall and relearning were both slightly negatively accelerated, and with five interpolated lists, forgetting was almost complete as measured at recall.

From the standpoint of careful analysis Twining's study is incomplete. No data are given on overt inter-list intrusions during recall and relearning. Of late, these intrusions have come to assume considerable importance in deriving specific postulates for a theory of RI

[1] A complete summary of experimental work on RI since 1935 will be found in Swenson's monograph (15). Work prior to 1935 has been reviewed by Britt (2).

(10, 12, 13, 16). Furthermore, Twining interpolated the lists midway in the rest period. Since the locus of interpolation is one variable influencing RI, it is difficult to place the results in their proper perspective. Most experimenters, when not specifically studying the influence of the locus of interpolation, have introduced the interpolated material immediately after the original learning. Hence, most of the data now available are contingent upon that condition.

No other experimenter has systematically varied the number of interpolated lists. In a recent study, Bugelski (3) had subjects learn four consecutive lists of paired nonsense syllables in which the same stimulus was used for all four lists. He then compared the recall of the first list with the recall of the first list of another group of four unrelated lists. The decrement in retention was greater in the first instance. But here again no quantitative data are given on the behavioral correlates of the inhibition, such as overt intrusions.

It is evident, then, that there is a paucity of information on RI as a function of the number of interpolated lists. Completely lacking is any information on the inter-list errors accompanying the recall and relearning attempts. Experiment A was designed to obtain data on the recall and relearning of an original list of paired adjectives after the interpolation of 2, 4, and 6 lists.

RI as a Function of the Number of Trials on a Single Interpolated List

This variable has received considerable experimental attention, and the results are remarkably consistent in spite of the fact that a wide divergence of methods and materials has been used. Experiments by McGeoch (8), Lahey (6), Melton and Irwin (12), and Thune and Underwood (16) have led to the unequivocal generalization that (with other things being equal) an increase in the number of interpolated trials results in an increase in RI, with maximal inhibition obtaining with intermediate degrees of interpolated learning. Repetition of the interpolated material leading to extreme overlearning produces a decrease in the inhibition (8, 12).

Experiment B of the present series was not designed to verify or refute the above generalization, but primarily to provide a precise control for experiment A. In experiment A, 2, 4, and 6 interpolated lists were presented for four trials each. In experiment B, a single list was presented for 8, 16 and 24 trials. Thus, while the number of trials in both experiments was the same, the number of lists learned during those trials was varied.

The major purpose for comparing the inhibition of experiments A and B was to ascertain the differences in extent and character of the inhibition produced by the two different sets of operations. It would have been possible to execute experiment A, determine the relationship between the inhibition and the varying number of lists, and then infer from prior studies on the degree of interpolation the differences in the inhibition resulting from the two operations. For exact measurement this method has little justification other than economy. Minor variations in the experiments always leave the question as to just how much effect, if any, these variations have on the results.

Conditions Influencing Proactive Inhibition

There are no published studies in which the retention of a verbal list was measured after the prior learning of two or more other lists. In fact, the amount

of data available on PI is exceedingly scant when compared with the enormous mass of data available on RI. This dearth of objective data on PI led McGeoch (9) to relegate it to a very minor role as a cause of forgetting. Theoretically, PI has received but little attention. Since the variables determining this form of inhibition must be closely related to those producing retroaction, an adequate theory of RI will probably constitute the fundamental basis of a theory of proaction. From the few published studies on PI it is possible to distinguish trends which indicate the importance of certain variables. The variables which seem to be most important are listed here.

1. There can be little doubt that *similarity* (formal or meaningful) between the first and second activities is an important condition determining PI (1, 13, 21). In fact, some confidence can be placed in assuming that without a certain amount of formal or meaningful similarity, reliable amounts of inhibition will not be present.

2. Serial position identity, without meaningful or formal similarity, does not seem capable of producing significant amounts of PI (10, 13, 20).

3. Presentation rate may be one variable that is more important in determining PI than RI (18). The slower the rate of presentation the less the PI.

4. The length of the temporal interval between the learning and the recall of the second list is an apparent variable which has received no systematic attention. If, after having learned a first list, A, a second list, B, is in the process of being learned, each new trial actually constitutes a retention test of the learning on the preceding trials. In testing for PI, all that is being done is to lengthen the time interval between any two arbitrarily chosen trials. In the usual memory drum operation the period of "rest" between trials is six to eight seconds. What will happen if this interval is increased to 1 minute, 5 minutes, 10 minutes, etc.? Since the studies reported have measured PI after 20 minutes rest and since PI has not been found after six to eight seconds rest,[2] some gradient of inhibition must necessarily be present as a function of the time or activity intervening between learning and the retention test.

It is apparent, however, that in comparison with the knowledge relative to RI, the known facts of PI are small. Experiment C of this series was designed to explore one of the dimensions of which PI was thought to be a function; namely, the number of prior lists.

C. THEORETICAL BACKGROUND OF THE PROBLEMS[3]

The theoretical problems with which the present experiments are concerned are limited almost exclusively to issues which have emanated from the two-factor theory of RI.

The two-factor theory is essentially an elaboration of the competition theory which developed primarily out of the long series of studies by McGeoch and his associates. In general terms, this competition theory interprets RI as resulting from the interaction of the two activities in such a way that competition of responses results in a decrement in performance. Most of the specific supporting evidence for the hypothesis comes from analyses of the similarity dimensions be-

[2] This statement is subject to modification by the particular trial on which the inhibition is measured. Early in the learning of the second list some retardation of learning may be noted (11). This inhibition, associative inhibition, may be only a special case of PI, or vice-versa.

[3] A brief résumé and evaluation of all current theories of RI can be found in McGeoch (9) and Swenson (15).

tween the two activities and from the observation of intrusions from the interpolated activity at the time of recall of the originally learned activity. There can be little doubt that this competition varies as a function of the similarity of the two materials (9, Chapter XI).

The competition theory, however, loses its specificity when variables other than similarity are considered. The two-factor theory, as an extension of the competition theory, has provided the first step toward bringing specificity to these other conditions. It has been concerned with competition of responses as a function of the degree of interpolated learning. The two-factor theory was formulated by Melton and Irwin (12) as a consequence of their experiment on RI as influenced by the degree of interpolation.

In brief, the two factors, as delineated by Melton and Irwin are: (1) a competition of responses at the time of recall and relearning, and (2) a weakening or "unlearning" of the original responses as a result of their non-reinforcement during the learning of the interpolated activity. The two factors are assumed to combine to make up the total RI as measured at recall. The experimental evidence for the theory as well as the logic used in its derivation need not be reviewed here, as the experimental and theoretical curves forming the basis for the theory can be found in three different sources (9, 12, 16).

Recent evidence and analyses have placed considerable limitation on the two-factor theory as it was originally formulated. It has been shown that some of the assumptions on which the theory is based are probably unsound and that certain of the logical implications of the theory lead to contradictions (16). However, the basic hypothesis of unlearning (weakening of responses by non-reinforcement) appears to remain as a fruitful construct. Since this unlearning construct promises to be a useful one, it has seemed desirable to try to get some notion of the characteristics of the process.

The present experiments were set up primarily to gather systematic data along little explored dimensions. At the same time the experiments were aimed at testing an interpretation as to the nature of the unlearning process. It has been suggested (16) that the amount of unlearning of the original responses which takes place during the interpolated learning may cease after a "few" trials on the interpolated list. It was reasoned that if weakening of the original list is taking place, some evidence of this weakening should be observed. By definition, the unlearning of the original responses results from the occurrence of these responses, either overtly or implicitly, during the interpolated learning. That is, with non-reinforcement in the learning of the second (interpolated) list, these original responses are assumed to be weakened. Since associative inhibition is measured at this locus it was considered possible that the duration of the unlearning process would be indicated by the number of trials for which there is evidence of associative inhibition in the learning of the second list. Associative inhibition is usually found to be quite transitory. The term "few" has been used since the persistence or transitoriness of associative inhibition is dependent upon certain conditions specific to each experiment.

It has been demonstrated (13) that one of the implications of the unlearning theory is that RI will be greater than PI. This follows from the fact that the second list (interpolated list) does not go

through an unlearning process and consequently should be stronger at the time of recall. The implication has received experimental confirmation from two sources (10, 13). Now, if unlearning takes place for a "few" trials only (as posited above), then the difference between PI and RI should be constant beyond these "few" trials regardless of the amount or degree of interpolation. Experiments A and C were arranged to provide a test of this hypothesis. Experiment A has 2, 4, and 6 lists *following* the list to be recalled, and experiment C has 2, 4, and 6 lists *preceding* the list to be recalled. If the hypothesis as to the cessation of unlearning after a "few" trials is to be confirmed, or at least retained as tenable, the difference in the recall between the two experiments (at corresponding points) should be relatively constant. To reject the hypothesis, some consistent trend of increasing or decreasing difference should be observed.

Chapter II

Experimental Procedure

A. EXPERIMENT A

Conditions

Experiment A was designed to measure the influence of the learning of 2, 4, and 6 interpolated lists (ILs) on the retention of an originally learned list. A scheme of the conditions used to measure this influence is shown in Table 1. The symbols A-B represent a pair of two-syllable adjectives used as the original learning for all conditions. The paired adjectives of the ILs are represented by A-C, A-D, etc., in which each IL requires that the subject (S) associate a new response to an old stimulus. Thus, under condition IVa, seven different responses may be associated with the same stimulus.

The original list (OL) under all conditions was exposed until the S had correctly anticipated six or more of the response adjectives. All ILs were presented for four trials (including the first or study trial) regardless of the level of acquisition attained at the end of those four trials. Relearning of the OL was always carried until the S had correctly anticipated all adjectives for two successive trials.

Condition Ia, in which no ILs were learned, is the control for the three work conditions, IIa, IIIa, and IVa. A basic rest period of 25 min. between the cessation of original learning and recall has been used. With 2, 4, and 6 ILs, this period was reduced to the intervals shown in Table 1. Approximately 45 sec. elapsed between the learning of each list. This period was required in order that the experimenter could change lists on the drum. During all of the major rest periods the Ss ranked mounted cartoons.

Lists

All lists were made up of 10 pairs of two-syllable adjectives. An attempt was made to eliminate any formal or meaningful similarities (16) and to make the major interfering characteristic of the pairs that which is inherent within the A-B, A-C, etc., learning procedure.

Four sets of experimental lists were made up, each set consisting of seven lists. All of the lists of any one set had the same stimulus words but different response words. From each of the four sets, one list was selected by chance to be used as the A-B (original) list for that

Table 1

Schedule of Events Used to Measure Retroactive Inhibition as a Function of the Learning of 2, 4, and 6 Interpolated Lists. The Original Learning, A-B, Continued Until the Subjects Correctly Anticipated Six or More Responses. All Interpolated Lists Were Presented for Four Trials and Relearning of the Original List Was Carried to Two Successive Errorless Trials.

Conditions	Original Learning	Rest And/Or Interpolated Learning		Relearning
Ia*	A-B		-25′-	A-B
IIa	A-B	A-C, A-D	-17′16″-	A-B
IIIa	A-B	A-C, A-D, A-E, A-F	-9′12″-	A-B
IVa	A-B	A-C, A-D, A-E, A-F, A-G, A-H	-1′18″-	A-B

* All four conditions listed here have their counterparts in experiments B and C. To identify the specific condition with the proper experiment, all references to conditions will have the subscripts a, b, and c, referring to experiments A, B, and C, respectively.

set. These four lists were always used as the OL and all others as the ILs.

In order to enforce paired-associates learning and minimize serial learning of the responses, the experimenter presented the adjectives in three different orders. In addition, in changing from list to list during the interpolated learning, the experimenter maintained a constant order regardless of the new list. Thus, if the fourth trial of the first IL employed order #2, the first trial of the second IL used order #3. All three orders of presentation were typed in capital letters on heavy white tape. Two blank spaces between each order afforded an 8-sec. rest period between each trial.

Counterbalancing

Each S served in all four experimental conditions after going through two practice sessions. With 24 Ss and four experimental conditions, a complete counterbalancing of these conditions was effected. Consequently, each S acted as his own control for the experimental variable. The four sets of experimental lists were used in successive order regardless of the condition so that each set of lists appeared with each condition an equal number of times. The ILs were counterbalanced in pairs in order to facilitate their handling. By this scheme a complete counterbalancing of pairs of lists was obtained for each block of six Ss.

Practice Controls

Two practice days preceded the four experimental days. These two days were provided to (a) acclimate the S to the experimental situation, (b) to insure that all instructions were understood as shown by their execution, and (c) to accommodate the great practice effects which occur with initial learning. During these practice days the Ss learned two lists to a criterion of two successive errorless trials and four lists for four trials each. The latter provided practice in going quickly from one IL to another.

TABLE 2

Schedule of Events Used to Measure Retroactive Inhibition as a Function of 8, 16, and 24 Trials on a Single Interpolated List.

Conditions	Original Learning	Rest And/Or Interpolated Learning	Relearning
Ib	A-B	-25'-	A-B
IIb	A-B	A-C (8 trials) -17' 6"-	A-B
IIIb	A-B	A-C (16 trials) -9'12"-	A-B
IVb	A-B	A-C (24 trials) -1'18"-	A-B

It is necessary to provide one practice control during the experimental sessions. If one S commenced with condition Ia, in which there is no interpolation, and another S started with IVa, in which there are six ILs, the second S would receive considerably more practice than the first so that on the second experimental day they would not be starting their respective conditions with equal prior practice. Hence, all conditions must be provided with the same amount of practice as that afforded by condition IVa. This was accomplished by having the Ss learn the required number of lists *after* the relearning of the OL. Thus, on condition Ia, six additional lists were learned for four trials each after the relearning of the A-B list. On condition IIa, four additional lists were learned, and on condition IIIa, two additional lists. At the end

of any experimental day all Ss had had the same formal opportunity to maintain a constant level of practice.

Subjects

Of the 24 Ss, 16 were women and 8 were men. All were undergraduate students and the majority of them were enrolled in the elementary psychology course. Most of the Ss served six consecutive days, but at no time did the period between sessions extend beyond four days.

B. EXPERIMENT B

Table 2 shows the schedule of events used for the four conditions of this experiment. It will be noted that condition Ib is identical to condition Ia of experiment A. The identity of these conditions allows for a comparison of the two groups of Ss.

Since the procedure of experiment B follows closely that outlined for experiment A, only the essential differences will be noted here. The interpolated learning in experiment B varies from that in experiment A in that 8, 16, and 24 trials were given on a single list on conditions IIb, IIIb, and IVb, respectively. Since six different ILs for each set of lists were used in experiment A, these same six lists (as well as the same OLs) were used, with a different list learned by each block of four Ss.

In order to keep the temporal intervals exactly the same as in experiment A, the Ss were given a 45-sec. rest period after every fourth trial of the IL. This corresponds to the 45-sec. employed for changing the lists in experiment A. The day to day practice level was maintained by giving the appropriate number of trials on the IL after the relearning of the OL. The 24 Ss of experiment B consisted of 14 women and 10 men, all undergraduates.

C. EXPERIMENT C

Table 3 shows the schedule of events used to measure PI as a function of the number of prior lists (PLs). As will be seen, the conditions duplicate those of experiment A except that the lists used for the interpolated learning in experiment A now appear as the PLs of experiment C. The major lists (A-B) in both experiments were recalled after 25 min., but in experiment A the original learning of these lists was *followed* by 2, 4, and 6 lists, whereas in experiment C, the learning of the A-B list was *preceded* by 2, 4, and 6 lists.

The group of 24 Ss of the experiment was made up of 13 women and 11 men, all undergraduates.

TABLE 3

Schedule of Events Used to Measure Proactive Inhibition as a Function of the Learning of 2, 4, and 6 Lists Prior to the Learning of the List to Be Recalled (A-B)

Conditions	Prior Learning	Original Learning	Rest	Relearning
Ic		A-B	25′	A-B
IIc	A-D, A-C	A-B	25′	A-B
IIIc	A-F, A-E, A-D, A-C	A-B	25′	A-B
IVc	A-H, A-G, A-F, A-E, A-D, A-C	A-B	25′	A-B

Chapter III

Results

The results of the present experiment will be treated in four sections under the following headings: (A) RI of experiment A, (B) RI of experiment B, (C) PI of experiment C, and (D) inter-experiment comparisons.

A. RI OF EXPERIMENT A

Degree of Original Learning

Since an acquisition criterion has been used for the original learning of each condition, it is necessary to show the exact degree of learning attained and the number of trials required to attain it. The essential data are shown in Table 4, under three different categories. For all measures the level of acquisition was relatively equal for the four conditions. The greatest difference in the total plusses (correct responses) on the last trial is between conditions IIIa and IVa. This difference of .34 ± .21 yields a t value of 1.62.[4] With respect to the total plusses on all of the original learning trials, the greatest difference obtains between conditions Ia and IIIa, this difference being 2.13 ± 2.18 (t = .98). The largest difference in trials to reach the criterion of six correct responses is between conditions Ia and IVa. This difference is .59 ± .72 (t = .82). Since none of these differences is reliable, any significant differences appearing during recall and relearning must be a product of the major variable, i.e., the number of ILs.

RI at Recall

The major data from experiment A are to be found in the amount of RI as shown by the first few relearning trials after interpolation and rest. The mean correct anticipations for the first five relearning trials, together with the percentages of inhibition, are shown in Table 5.[5] A graphical presentation is made in Figure 1.

The most important fact shown in Table 5 and Figure 1 is the increase in RI with increases in the number of ILs. This is especially evident on the first recall trial. On this trial the differences between condition Ia (rest) and the three interpolated conditions represent highly reliable amounts of RI. With six ILs, forgetting is almost complete. On this condition (IVa), only three Ss gave cor-

Table 4

Measures of the Degree of Original Learning for All Conditions as Determined by the Total Plusses (Correct Responses) on the Last Trial of Original Learning, the Total Plusses on All Original Learning Trials, and the Trials Required to Reach Six Correct Responses. Experiment A.

Condition	Total Plusses on Last Trial		Total Plusses on All OL Trials		Trials to Reach 6 Plusses	
	M	σ_M	M	σ_M	M	σ_M
Ia	6.46	.12	22.42	2.44	7.13	.74
IIa	6.38	.11	21.04	1.86	6.75	.62
IIIa	6.29	.12	20.29	1.53	6.63	.51
IVa	6.63	.15	21.13	1.47	6.54	.52

[4] All measures of reliability are sigma of the mean. With 23 degrees of freedom, a t value of 2.81 is taken as a very significant mean difference (4).

[5] Percent of inhibition has been calculated by the usual formula, (Rest — work/rest) × 100.

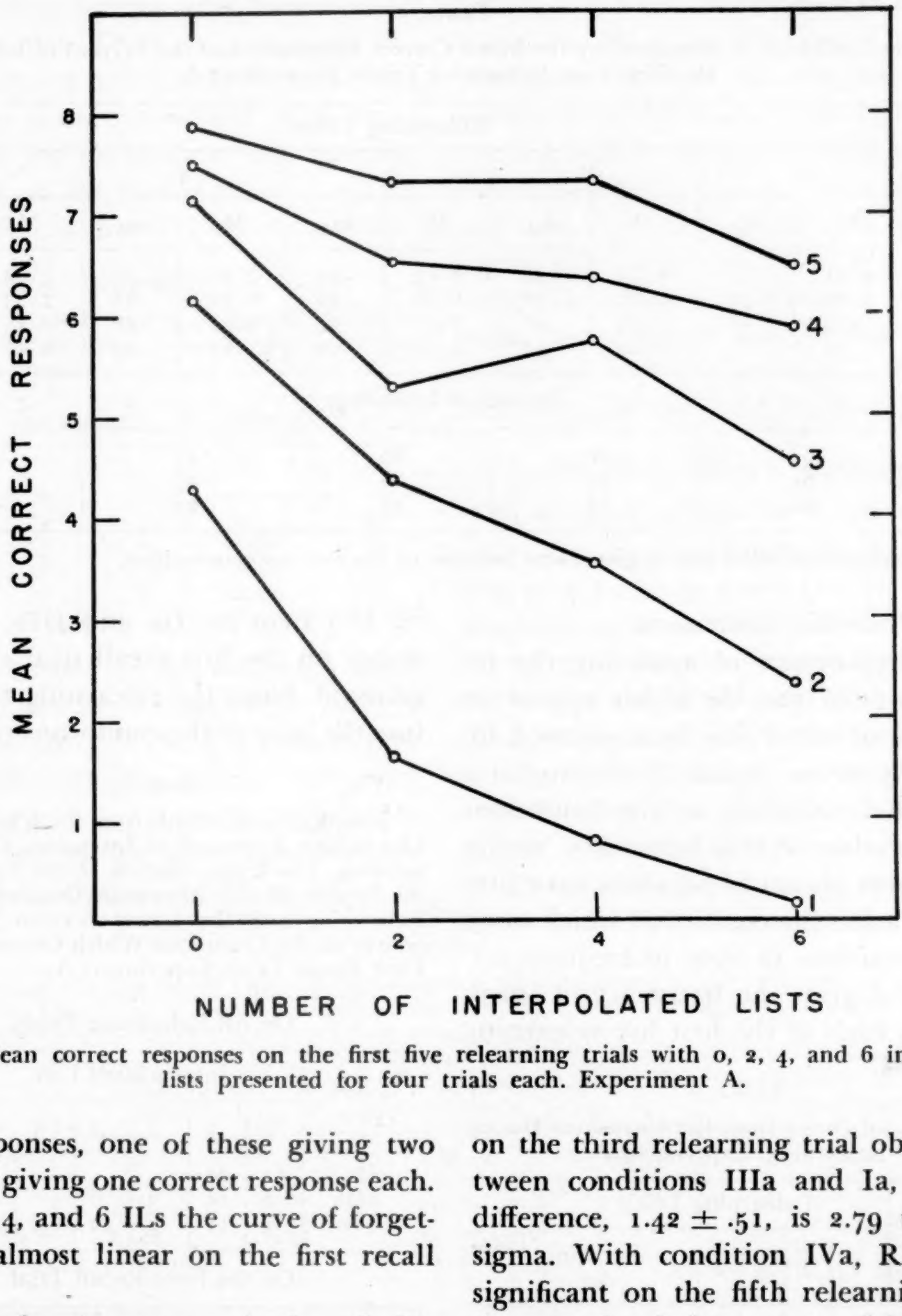

FIG. 1. Mean correct responses on the first five relearning trials with 0, 2, 4, and 6 interpolated lists presented for four trials each. Experiment A.

rect responses, one of these giving two and two giving one correct response each. With 2, 4, and 6 ILs the curve of forgetting is almost linear on the first recall trial.[6]

Of further importance is the relative persistence of the RI throughout the five trials under consideration. All experimental conditions show significant differences throughout the first three relearning trials. The smallest difference on the third relearning trial obtains between conditions IIIa and Ia, yet this difference, 1.42 ± .51, is 2.79 times its sigma. With condition IVa, RI is still significant on the fifth relearning trial, the mean loss being 1.37 ± .48 ($t = 2.85$). The relative persistence of the RI under the different conditions can be seen clearly in Figure 1.

These results leave little doubt that RI increases directly with an increase in the number of ILs under the conditions of the present experiment. Thus, these results are a confirmation of Twining's (17) work with serial learning of nonsense syllables.

[6] On the first recall trial the difference between conditions IIa and IIIa is .88 ± .33 ($t = 2.67$). The difference between conditions IIa and IVa is 1.50 ± .27 ($t = 5.56$), and the difference between IIIa and IVa is .62 ± .17 ($t = 3.65$).

TABLE 5

Retroactive Inhibition as Measured by the Mean Correct Responses and the Percent of Inhibition on the First Five Relearning Trials. Experiment A.

Conditions	Relearning Trials									
	1		2		3		4		5	
	M	σ_M	M	σ_M	M	σ_M	M	σ_M	M	σ_M
Ia	4.21	.32	6.13	.33	7.13	.32	7.46	.35	7.83	.35
IIa	1.67	.35	4.33	.36	5.25	.39	6.50	.38	7.33	.34
IIIa	.79	.18	3.58	.26	5.71	.37	6.33	.36	7.33	.34
IVa	.17	*	2.29	.32	4.46	.40	5.83	.33	6.46	.36
	Percent of Inhibition									
IIa	60		29		26		13		6	
IIIa	81		42		20		15		6	
IVa	96		63		37		22		17	

* No measure of reliability is given here because of the few responses given.

Overt Inter-list Intrusions

The importance of analyzing the intrusions from the IL which appear at the time of recall has been stressed increasingly as one means of arriving at a better understanding of the conditions which produce RI. A behavioral theory of RI must almost of necessity take into consideration the conditions which cause these intrusions to vary in frequency.

Table 6 gives the frequency of intrusions on each of the first five relearning

TABLE 6

Frequency of Overt Inter-list Intrusions During Relearning. Experiment A.

Condition	Relearning Trials						Total
	1	2	3	4	5	Remainder	
IIa	26	6	1	0	1	1	35
IIIa	26	4	1	0	0	1	32
IVa	28	5	5	1	0	2	41

trials together with the total occurring on all other trials. Primary interest in these data lies in the relative constancy of the intrusions for the first recall trial regardless of the degree of interpolation. Although in terms of total frequency on all trials there are a few more intrusions on IVa than on IIa and IIIa, the constancy on the first recall trial cannot be gainsaid. Since the relearning trials confuse the issue of the conditions producing

TABLE 7

Frequencies of Words from Each Interpolated List Which Appeared as Intrusions During Relearning. The Upper Section of the Table Shows the Source of All Intrusions Occurring During Relearning and the Lower Section Shows the Source of the Intrusions Which Occurred on the First Recall Trial. Experiment A.

Condition	Interpolated List						Total
	1	2	3	4	5	6	
	On All Relearning Trials						
IIa	12	23					35
IIIa	6	15	5	6			32
IVa	5	11	6	12	3	4	41
	On the First Recall Trial						
IIa	9	17					26
IIIa	6	14	1	5			26
IVa	3	9	4	10	1	1	28

intrusions, the major concern must be with those on the first recall trial.

Table 7 shows the source of the intruding items, i.e., the serial position of the ILs from which the intrusions appeared. The lists are numbered in order from 1 through 6, and the frequency of

intrusions which came from these various lists are noted. Thus, on condition IIa, 12 intrusions at recall came from the first IL and 23 from the second. The lower section of the table shows the number appearing on the first recall trial alone.

It should be noted that some intrusions came from all ILs, although there was considerable irregularity.[7] But of more importance is the fact that, except on condition IIa, the greatest frequency of intrusions from any list was never from the last IL learned. If the lists are combined in pairs (1 and 2, 3 and 4, 5 and 6), the point to be made is brought out more clearly. This fact is that on conditions IIIa and IVa, the majority of intrusions do not come from the last ILs learned. This, and the finding noted earlier that intrusions on the first recall trial are relatively constant in number regardless of the number of ILs, constitutes the major experimental findings from the intrusions data for experiment A, and as such will receive further attention in the theoretical considerations.

Table 8

Mean Trials Required to Relearn the Original List to One Perfect and Two Successive Perfect Trials. Experiment A.

Condition	One Perfect		Two Perfect	
	M	σ_M	M	σ_M
Ia	7.83	.90	9.33	1.06
IIa	10.33	1.05	11.86	1.14
IIIa	10.17	.82	12.54	1.50
IVa	8.67	.70	10.21	1.01

RI in Trials to Reach Mastery

RI is often present in recall without producing any significant deleterious effects on relearning scores (10, 12, 13, 16). A relearning score is defined as the number of trials required to reach an arbitrary criterion of mastery. The data on these relearning scores for experiment A are shown in Table 8 in terms of the number of trials required to reach one perfect and two successive perfect trials. In all cases the mean number of trials to relearn under the work conditions is greater than for the rest condition, though in no instance is the difference reliable.

Table 9

Measures of the Degree of Original Learning for All Conditions as Determined by the Total Plusses on the Last Trial of Original Learning; the Total Plusses on All Original Learning Trials, and the Trials Required to Reach Six Correct Responses. Experiment B.

Condition	Total Plusses on on Last Trial		Total Plusses on All OL Trials		Trials to Reach Six Plusses	
	M	σ_M	M	σ_M	M	σ_M
Ib	6.33	.21	17.83	1.52	5.67	.49
IIb	6.42	.14	20.53	1.74	6.63	.54
IIIb	6.50	.16	21.42	1.90	7.33	.66
IVb	6.58	.18	18.83	1.33	6.25	.46

B. RI OF EXPERIMENT B

Degree of Original Learning

Again, before making any inter-condition comparisons, it is necessary to show

[7] Much of this irregularity can probably be allocated to an experimental artifact. As explained in Chapter II, the ILs were counterbalanced in pairs to facilitate their handling. Due to chance, it occurred that the odd lists as a group were somewhat more difficult to learn than the even lists. This was shown by the lower level of acquisition attained on these odd lists. It will be observed in Table 7 that the odd lists produced fewer intrusions than the even lists. Part of this is undoubtedly due to the lower level of acquisition attained on the four trials of these odd numbered ILs.

the degree of learning attained on the OLs. These data are shown in Table 9. As measured by the total plusses on the last original learning trial the greatest difference is between conditions Ib and IVb. This difference, .25 ± .16, is 1.56 times its sigma. In terms of the total plusses on all original learning trials the largest difference obtains between conditions Ib and IIIb. This difference is 3.59 ± 2.51 (t = 1.43). With respect to the mean trials to reach the criterion of six correct responses, the greatest difference is between conditions Ib and IIb, being 1.66 ± .80 (t = 2.08). Although these differences are larger than was found for experiment A, none of them is reliable enough to prohibit the desired comparisons at recall and relearning.

RI at Recall

The first five relearning trials are treated in the same manner as for experiment A. Table 10 presents the tabular data.

All three work conditions, with 8, 16 and 24 interpolated trials on a single list, yield reliable amounts of RI on the first recall trial. However, there are no reliable differences obtaining between the three work conditions. The greatest difference is between conditions IIIb and IVb, but this difference is only .46 ± .35 (t = 1.39). Yet, although the amount of RI on the first recall trial is approximately equal for all three degrees of interpolation, differences arise as relearning continues. There is little difference in the characteristics of the curves for conditions IIb and IIIb as shown in Figure 2, unless the slight indication that RI persists longer in condition IIIb is reliable. At the end of five relearning trials the RI is still significant for both IIb and IIIb.[8] The inhibition on condition IVb, however, shows a more rapid rate of dissipation. At the end of the fourth relearning trial the difference between this condition and Ib is 1.25 ± .50 (t = 2.50), but at the close of the fifth relearning trial the difference is reduced to .54 ± .43 (t = 1.26).

These data would seem to indicate that RI dissipates more rapidly with the high degree of interpolated learning. In view of the fact that Melton and Irwin

TABLE 10

Retroactive Inhibition as Measured by the Mean Correct Responses and the Percent of Inhibition on the First Five Relearning Trials. Experiment B.

Condition	Relearning Trials									
	1		2		3		4		5	
	M	σ_M	M	σ_M	M	σ_M	M	σ_M	M	σ_M
Ib	4.38	.18	6.04	.31	7.50	.23	7.75	.25	8.00	.25
IIb	1.58	.20	3.88	.31	5.21	.35	6.00	.29	6.88	.24
IIIb	1.67	.23	4.33	.35	5.04	.31	5.92	.40	6.33	.45
IVb	1.21	.23	4.25	.34	5.46	.36	6.50	.40	7.46	.34
	Percent of Inhibition									
IIb	64		36		31		23		14	
IIIb	62		28		33		24		21	
IVb	72		30		27		16		7	

[8] The difference between Ib and IIb at the end of five relearning trials is 1.12 ± .36 (t = 3.11). The difference between Ib and IIIb at the same locus is 1.67 ± .53 (t = 3.15).

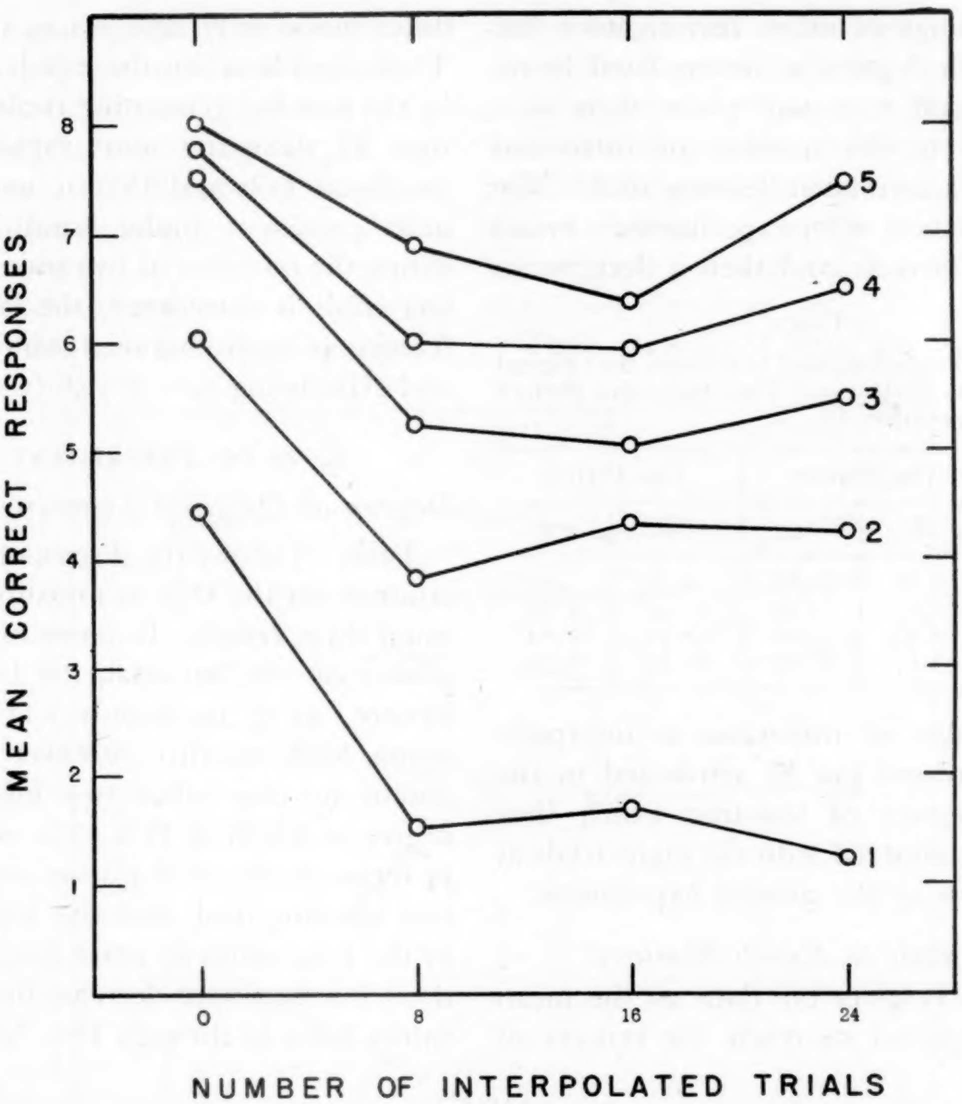

FIG. 2. Mean correct responses on the first five relearning trials with 0, 8, 16, and 24 trials on a single interpolated list. Experiment B.

(12) found a substantial reduction in RI with high degrees of interpolated learning, and that similar trends have been noted by McGeoch (8), there seems little doubt that the evidence here is further corroboration of these findings. The relearning scores, to be presented later, further substantiate the indication that the faster dissipation of RI with high degrees of interpolated learning is a reliable phenomenon.

Overt Inter-list Intrusions

As shown in Table 11, the trend of intrusions as a function of the degree of interpolated learning is relatively unequivocal. There is a continued decrease in the frequency of intrusions with an increase in the degree of interpolated learning whether measured in totals or the number on the first recall trial.

In general, these results substantiate

TABLE 11

Frequency of Overt Intrusions During Relearning. Experiment B.

Condition	Relearning Trials						Total
	1	2	3	4	5	Remainder	
IIb	24	5	1	3	3	3	39
IIIb	9	0	4	0	3	3	19
IVb	3	1	0	1	1	5	11

the findings of other investigators (12, 16). With degrees of interpolated learning beyond a certain point there is a decrease in the number of intrusions without a correlated decrease in RI. The fact that these other experimenters found first an increase and then a decrease in

TABLE 12

Mean Trials Required to Relearn the Original List to One Perfect and Two Successive Perfect Trials. Experiment B.

Condition	One Perfect		Two Perfect	
	M	σ_M	M	σ_M
Ib	6.96	.68	9.33	.95
IIb	10.17	1.16	11.33	1.21
IIIb	10.25	.98	12.54	1.24
IVb	9.67	1.19	11.25	1.32

the number of intrusions as interpolation increased can be attributed to the lower degrees of learning which they used as compared with the eight trials as the lowest in the present experiment.

RI in Trials to Reach Mastery

Table 12 gives the data on the mean trials required to reach the criteria of one perfect and two successive perfect trials. The difference between conditions Ib and IIb in the mean number of trials to reach one perfect is 3.21 ± 1.38, which yields a t value of 2.33. The difference between conditions Ib and IIIb is highly reliable, being 3.29 ± 1.07 ($t = 3.07$). When Ib and IVb are compared, the difference is only 2.71 ± 1.49 ($t = 1.82$). These data bear out the trends indicated by the first five relearning trials, namely, that RI dissipates most rapidly under condition IVb and that it tends to be most persistent under condition IIIb. When the criterion of two successive perfect trials is considered, the largest difference is again between conditions Ib and IIIb, being 3.21 ± 1.36 ($t = 2.36$).

C. PI OF EXPERIMENT C

Degree of Original Learning[9]

Table 13 shows the degree of learning attained on the OLs as measured by the usual three criteria. In terms of the total plusses on the last trial, the largest difference, .21 ± .19, is only 1.11 times its sigma. Such equality, however, does not obtain for the other two measures of degree of learning. It is to be noted that in terms of the total plusses on all original learning trials and also with respect to the total trials to reach the criterion, there is a consistent decrease in the mean values from Ic through IVc. Not only is the trend consistent, but the difference between conditions Ic and IVc is re-

TABLE 13

Measures of the Degree of Original Learning for All Conditions as Determined by the Total Plusses on the Last Trial of Original Learning; the Total Plusses on All Original Learning Trials, and the Trials Required to Reach Six Correct Responses. Experiment C.

Condition	Total Plusses on Last Trial		Total Plusses on All OL Trials		Trials to Reach Six Plusses	
	M	σ_M	M	σ_M	M	σ_M
Ic	6.37	.13	19.71	1.84	6.49	.59
IIc	6.54	.14	17.33	1.78	6.08	.58
IIIc	6.58	.16	17.13	1.65	5.67	.60
IVc	6.38	.11	15.46	1.35	5.38	.38

[9] The terms "original lists" and "original learning" are not appropriate for these lists since they *follow* the learning of the other lists. However, since they are the lists to be recalled and are comparable in every other way to the "real" original lists of experiments A and B, the terminology will be retained.

liable when measured in terms of total plusses on all trials. The difference is 4.25 ± 1.36, which yields a t ratio of 3.13. Considering the trials to reach six correct responses, the difference between the same two conditions is $1.11 \pm .50$ with a t value of 2.22.

This phenomenon of more rapid learning of the OLs the greater the number

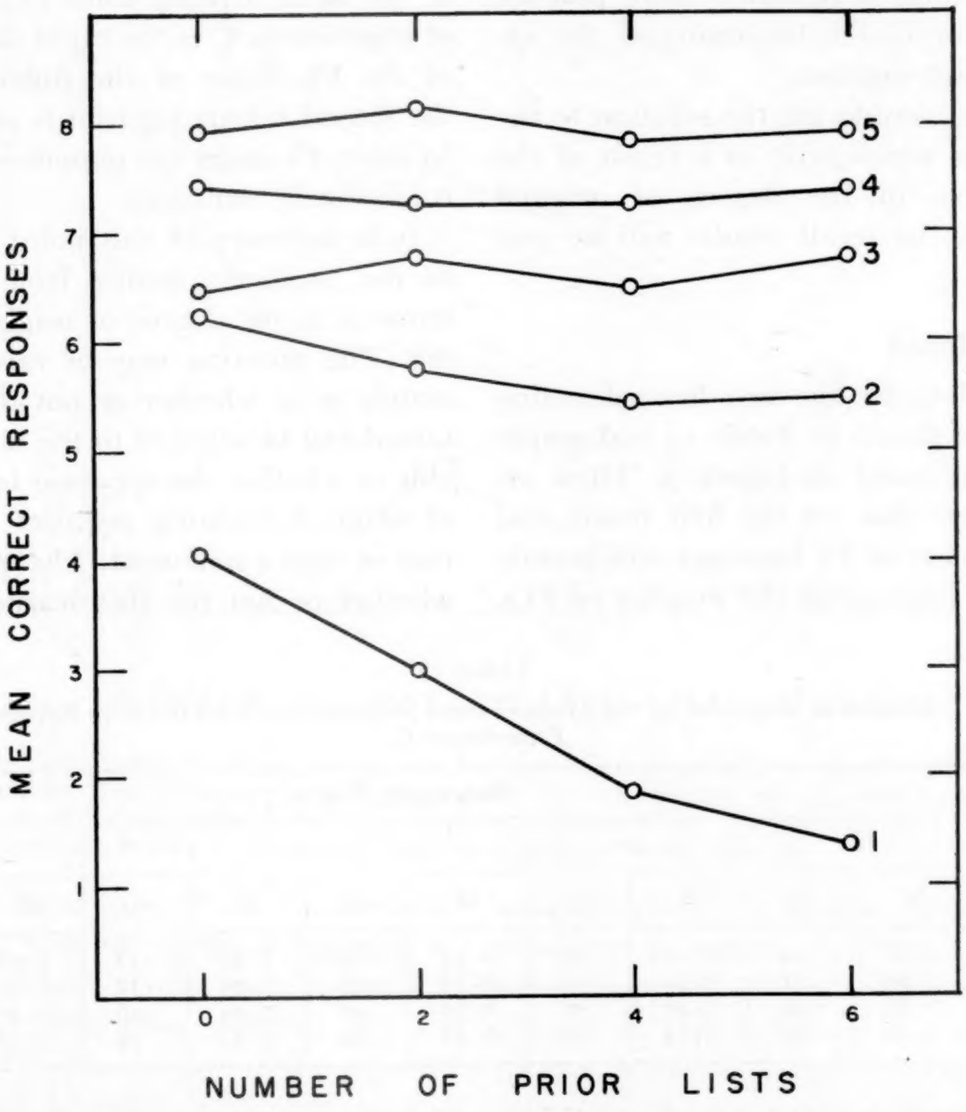

FIG. 3. Mean correct responses on the first five relearning trials with 0, 2, 4, and 6 prior lists presented for four trials each. Experiment C.

of PLs would be subsumed under the generic term of positive transfer. Since the list to list relationship involved (A-B, A-C, etc.) is of the nature that produces negative transfer early in the learning of each list, this positive transfer which occurred can probably be identified with the residual practice effects, i.e., the S is learning better how to learn. The entire data on this positive transfer in experiment C along with the data on the associative inhibition which occurred in learning the series of six lists have been published elsewhere (19).

These practice effects are especially difficult to control in proactive operations where a considerable amount of learning must precede the learning of the list that is to be recalled. By use of extra practice lists *after* the major learning, the day to day practice is held con-

stant for all Ss, but such equalization does not extend *within* the experimental period when different degrees of prior learning are considered. The experimenter cannot give the practice equalization lists before the major learning, for at once he is faced with the problem of associative inhibition from the practice material to the major material. The best solution is probably more practice days prior to the beginning of the experimental sessions.

Before considering the solution to the problems which arise as a result of the differences in the degree of original learning, the recall results will be presented.

PI at Recall

The data for the first five relearning trials are shown in Table 14 and graphically presented in Figure 3. These results show that on the first recall trial the amount of PI increases consistently with an increase in the number of PLs. All comparisons of the work conditions with the rest condition yield reliable differences.[10] The difference between the recall on conditions IIc and IIIc is fairly reliable, but the difference between conditions IIIc and IVc is only $.44 \pm .45$ ($t = .98$). Although no confidence can be placed in this difference, the consistency of the curve (Figure 3) would indicate strongly the reliability of the trend. The percentage of PI on the first recall trial is 26.5, 54.4, and 65.2 for conditions IIc, IIIc, and IVc, respectively.

In comparison with experiments A and B, the most striking point of the result of experiment C is the rapid dissipation of the PI. None of the differences on the second relearning trial is significant. In short, PI under the present conditions is extremely transitory.

It is necessary at this point to revert to the problems arising from the differences in the degree of original learning. The question may be raised legitimately as to whether or not the PI obtained can be allotted to the major variable or whether the apparent lower level of original learning requires qualification of such a statement. The question is whether or not the lists learned to the same criterion, but some more rapidly than others, will suffer equal amounts of decrement with equal amounts of prior learning. Now the degree of learning on the last trial of original learning for all conditions was fairly equal. The difference lies in the number of trials, hence the total correct responses given, in reaching the criterion. Superficially, at

TABLE 14

Proactive Inhibition as Measured by the Mean Correct Responses on the First Five Relearning Trials. Experiment C.

Condition	Relearning Trials									
	1		2		3		4		5	
	M	σ_M	M	σ_M	M	σ_M	M	σ_M	M	σ_M
Ic	4.08	.24	6.25	.35	6.54	.29	7.46	.32	7.92	.32
IIc	3.00	.31	5.75	.30	6.75	.28	7.29	.32	8.13	.28
IIIc	1.86	.34	5.46	.28	6.50	.41	7.29	.36	7.79	.34
IVc	1.42	.31	5.54	.32	6.71	.24	7.42	.34	7.92	.35

[10] The difference between Ic and IIc is $1.08 \pm .35$ ($t = 3.09$); between conditions Ic and IIIc the difference is $2.22 \pm .38$ ($t = 5.84$); and between Ic and IVc, the difference is $2.66 \pm .54$ ($t = 4.93$).

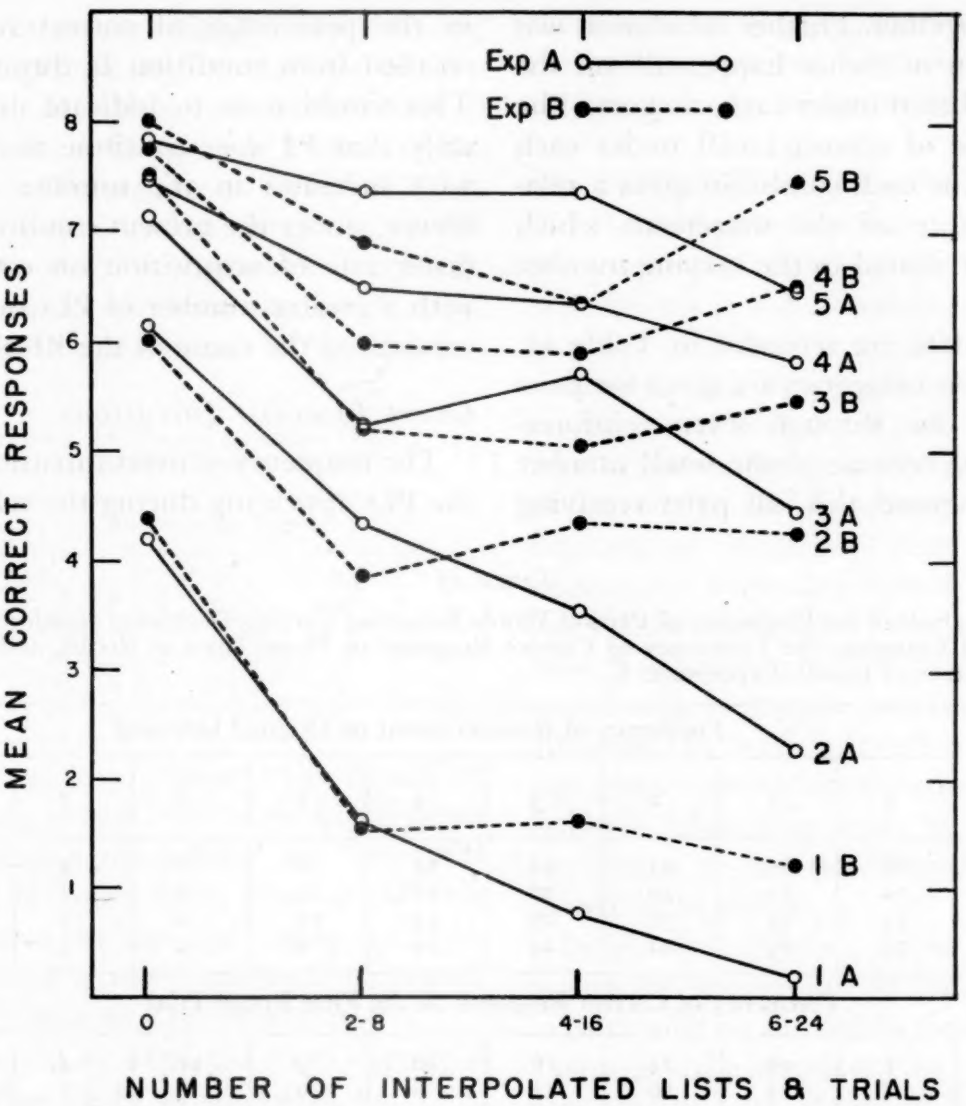

FIG. 4. A comparison of the RI during the first five relearning trials of experiments A and B. 1-A indicates the first relearning trial of experiment A; 1-B indicates the first relearning trial of experiment B, etc. Experiment A had 2, 4, and 6 interpolated lists presented for four trials each, whereas experiment B had 8, 16, and 24 trials on a single interpolated list.

least, the increase in PI at recall seems correlated with the speed of learning of the OLs. Consequently, some method is needed to determine whether the increase in PI with increase in the number of PLs can be safely attributed to this experimental variable.

In answering this question a specific item analysis of the various conditions has been made. The purpose is to secure an index of the decrement suffered under the various conditions for items of the OL having the same response strength but preceded by different numbers of lists. The procedure is simple and straightforward. Response strength or tendency is defined by the number of reinforcements, and a reinforcement is defined as the giving of a correct response. A single correct anticipation is called *one* reinforcement, two correct anticipations, *two* reinforcements, etc.[11] The record of each pair of words on the original learning was examined to determine the number of reinforcements received. All pairs receiving the same number of reinforcements were cate-

[11] For assumptions made in this procedure see Thune and Underwood (16).

gorized together. Further tabulation was made then of "what happened" on the first recall trial under each category. The percentage of correct recall under each category for each condition gives a relative measure of the decrement which can be attributed to the varying number of PLs.

These data are recorded in Table 15. The specific categories are given for pairs receiving one through seven reinforcements, but because of the small number of cases beyond this, all pairs receiving more than seven reinforcements are grouped together as the "remainder" category.

The major interest lies in the third section of the table, which shows the percentages of correct response for the various conditions after receiving equal number of response reinforcement. It will be noted that in all categories where the number of cases is large enough to be reliable, there is a consistent decrease in the percentage of correct responses recalled from condition Ic through IVc. This would seem to indicate unequivocally that PI *does* continue to increase with increases in the number of PLs. Hence, under the present conditions, the faster rate of acquisition on conditions with a greater number of PLs cannot be considered the cause of the PI obtained.

Overt Inter-list Intrusions

The frequency of overt intrusions from the PLs appearing during the relearning of the OL is shown in Table 16. Although the gross frequencies are less than in experiment A, it should be noted that, like experiment A, the frequencies are relatively constant for the various conditions. Not only is this true on the first recall trial but also when all relearning trials are combined.

The specific lists from which the intrusions occurred are shown in Table 17. Without exception the greatest num-

TABLE 15

Item Analysis of the Frequency of Pairs of Words Receiving Varying Degrees of Reinforcement on the Original Learning; the Frequency of Correct Response of Those Pairs at Recall, and the Percentage Correct at Recall. Experiment C.

Condition	Frequency of Reinforcement on Original Learning								
	0	1	2	3	4	5	6	7	More than 7
Ic	68	63	41	21	14	12	11	5	5
IIc	70	72	40	20	12	13	8	2	3
IIIc	74	55	57	22	13	11	2	3	3
IVc	77	67	44	24	14	4	4	5	1
	Frequency of Correct Response on the First Recall Trial								
Ic	1	19	24	16	10	9	11	4	5
IIc	4	11	20	12	6	9	6	1	3
IIIc	1	6	17	8	4	4	2	3	2
IVc	0	5	12	5	3	2	1	1	1
	Percent Correct on the First Recall Trial								
Ic	2	30	59	76	71	75	100	80	100
IIc	6	15	50	60	50	69	75	50	100
IIIc	1	11	30	36	31	36	100	100	67
IVc	0	8	27	21	21	50	25	20	100

ber of intrusions originate from the last PL irrespective of the number of lists involved. It will be remembered that in experiment A the general picture of the source of intrusions at recall was directly opposed to that shown for experiment C, i.e., the greatest frequency tended to appear from the first learned ILs. Both experiments have, however,

TABLE 16

Frequency of Overt Intrusions During Relearning. Experiment C

Condition	Relearning Trials						Total
	1	2	3	4	5	Remainder	
IIc	17	2	4	0	1	0	24
IIIc	18	2	2	0	0	0	22
IVc	20	3	1	0	0	0	24

something in common with regard to intrusion source. In both experiments the greatest frequency of intrusions tended to come from lists which were contiguous to the list being recalled. This trend is more apparent in experiment C than in experiment A.

As would be expected from the rapid dissipation of PI as shown in Figure 3,

TABLE 17

Frequencies of Words from Each Prior List which Appeared as Intrusions During Relearning. The Upper Section of the Table Shows the Sources of All Intrusions During Relearning and the Lower Section Shows the Source of Intrusion Appearing on the First Recall Trial. Experiment C.

Condition	Order of Prior Lists						Total
	1	2	3	4	5	6	
On All Relearning Trials							
IIc	5	19					24
IIIc	0	2	4	16			22
IVc	1	0	4	1	6	12	24
On the First Recall Trial							
IIc	3	14					17
IIIc	0	2	4	12			18
IVc	1	0	1	1	6	11	20

there were no significant differences in the mean trials required to reach one perfect and two successive perfect trials.

D. INTER-EXPERIMENT COMPARISONS

This section will be concerned with comparisons of differences occurring in experiments A and B and the differences between experiments A and C.[12]

The purpose in comparing the RI of experiment A with the RI of experiment B is to determine if 8, 16, and 24 trials on a single list produced different amounts of inhibition than the same number of trials distributed over 2, 4, and 6 lists, respectively. The data which have been presented in prior sections would suggest that the two functions are different. To make a direct comparison, the mean correct anticipations on the first five relearning trials for the work conditions of the two experiments are shown in Figure 4.

In general, Figure 4 shows that there is a greater increase in RI with increases in interpolation as used in experiment A. There is little difference in the inhibition shown with different numbers of trials on a single list (within the range investigated), whereas there is a consistent increase with 2, 4, and 6 lists. The RI is comparable in extent for the

[12] A comparison of these experiments necessitates that the Ss of each group are of near equal learning ability. Condition I is identical for each experiment and can be used for comparison. On the original learning the largest differences obtain between experiments A and B. The difference in total plusses on the last original learning trial is $.13 \pm .24$ ($t = .54$); the difference in total plusses on all trials is 4.59 ± 2.87 ($t = 1.60$); and in terms of trials to reach the criterion of six correct responses the difference is $1.46 \pm .89$ ($t = 1.64$). On the first recall trial the largest difference is between experiments B and C, being $.30 \pm .30$ ($t = 1.00$). To relearn to one perfect trial the largest difference is between conditions B and C, being 2.00 ± 1.48 ($t = 1.35$), and to relearn to two successive perfect trials the difference is 1.96 ± 1.75 ($t = 1.12$) for the same two conditions.

two experiments when either eight trials on a single list or four trials on each of the two lists is given. With the highest degree of interpolation in both experiments, however, the differences are marked. Not only is the initial RI greater for experiment A, but the persistence of the inhibition is much more apparent.

Regardless of the difficulties of a precise interpretation of the basis for these differences between the RI of experiments A and B, there can be little doubt that the inhibition produced by the two types of interpolation is different in amount and characteristic. Furthermore, the intrusion data presented previously indicate that the conditions making for intrusions were considerably different for the two experiments. Whereas the intrusions were relatively constant in number for experiment A under the various amount of interpolation, for experiment B there was a consistent decrease as the degree of interpolation on a single list increased.

All of these facts probably indicate a very complex interplay of response tendencies of the original and interpolated words, and probably additional factors which have not yet been suggested.

A comparison of experiments A and C is necessary to test the hypothesis stated in the first chapter that the amount of unlearning or weakening of the first list is a constant provided a "few" trials are given on the interpolated list or lists. Or, to state it differently, the hypothesis holds that the duration of the unlearning process is independent of the number of interpolated trials past these "few". Since the amount of unlearning has been defined operationally (13) as the difference between PI and RI, and since at least eight trials constituted the lowest degree of interpolated and prior learning, the prediction was made that the difference between RI and PI would be constant regardless of any further increase in the number of trials beyond

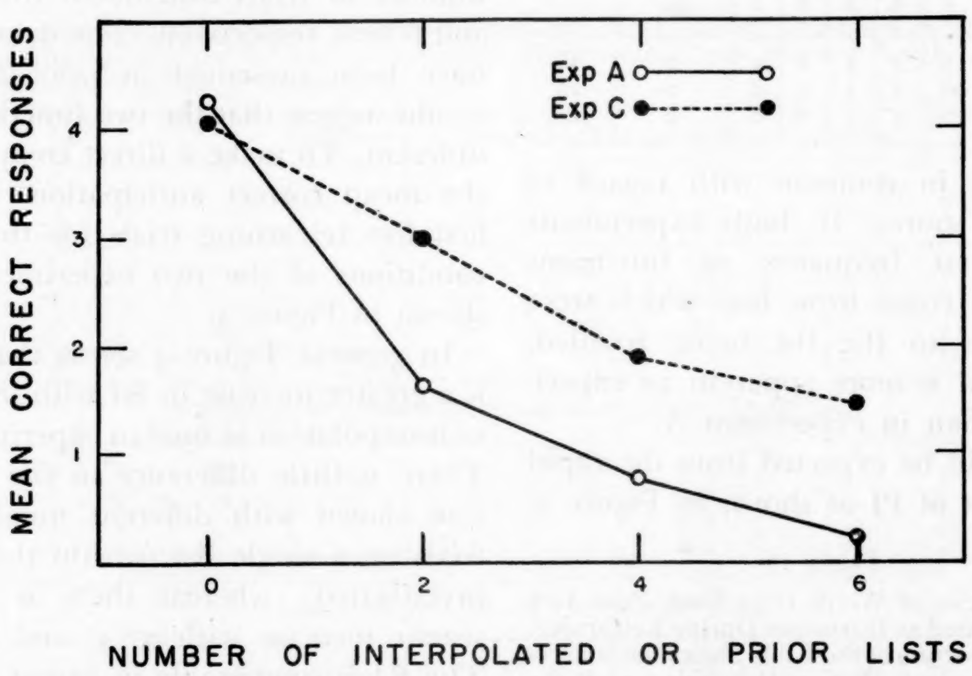

FIG. 5. Mean correct responses on the first recall trial after 0, 2, 4, and 6 interpolated lists (experiment A), and after 0, 2, 4, and 6 prior lists (experiment C). The upper curve indicates the amount of proactive inhibition and the lower curve the amount of retroactive inhibition.

eight. It will be remembered that the PI in experiment C had virtually disappeared by the second relearning trial. Hence, the concern here is with the differences on the first recall trial.

Figure 5 shows the curve of inhibition for the first relearning trial with varying degrees of interpolated and prior learning. It can be observed at once that the differences between the two curves at any empirical point are relatively equal. The exact differences are: with two ILs, 1.33; with four ILS, 1.07; and with six, 1.25. If the present experiments are accepted as an adequate test, the prediction that unlearning is a constant seems to be confirmed.

Chapter IV

Discussion of Results

The results of these experiments present a number of perplexing theoretical problems. Gibson's theory (5), based on stimulus generalization and differentiation, has no ready application to the present data because the stimulus words have been the same for both the OLs and ILs. The competition theory, as elaborated heretofore, has been entirely too general in nature, lacking specific postulates to show how competition varies as a function of changed conditions. Certainly this theory would be hard pressed to explain the results of experiments A and C in which inhibition increased without parallel increases in overt intrusions. Finally, little or no theoretical attention has previously been paid to the phenomenon of PI. In the following discussion an attempt has been made to augment the general statement of the competition theory by the use of more specific postulates. These concepts will first be developed in relation to the results of experiment B which is probably the least complex of the three situations, and then will be extended to the results of experiments A and C.

A. Interpretation of Experiment B

In attempting an interpretation of the results of experiments in which the variable manipulated has been the number of learning trials on the IL, the major findings as revealed by the present study and the investigations of Thune and Underwood (16) and Melton and Irwin (12) are: (1) the increase in the amount of RI as the number of interpolated trials increases up to at least 25 when there is a suggestion that it decreases slightly (e.g. at 40 trials); (2) the initial increase in the number of overt intrusions from the IL at recall up to 10 trials on the IL (when the number of trials on the OL was approximately five or six) and subsequent decrease to a very small value by 20 trials; (3) the increase in the number of "failures of response" with increase in number of interpolated trials.

Initially then, a theoretical interpretation of these phenomena needs to show: (1) why the interference takes two forms, overt intrusions and "failures to respond" and (2) how these two forms of interference vary with differences in the number of interpolated learning trials. The fundamental assumption to be made in the following attempt to state the interrelationships (laws) holding between these experimental variables is that *all measured RI is a function of the interference of the interpolated responses at the time of the attempted recall of the original responses.*

The amount and character of this interference is postulated further to be a function of two hypothetical constructs or intervening variables: (1) the associative strength of the IL responses and (2) the degree of differentiation of the competing response systems. These hypothetical variables must first, of course, be defined in terms of the manipulable experimental variables or conditions, variations of which result in different degrees or amounts of them; finally, their relations to the measured response variables must be specified in some manner.

The first of these variables—the associative strength of the IL responses—is postulated to be a negatively accelerated function of the number of correct an-

ticipations on this list. Presumably it approaches an asymptotic value as the number of trials increases. Two conditions or factors in these experiments would seem to be the major determinants of the degree of differentiation that exists between the two response systems corresponding to the two lists, original and interpolated: (1) the number of trials on the lists (since the number of trials on the OL is constant in these experiments, variation in this hypothetical construct so far as this factor is concerned would presumably be a function only of the differing number of trials on the IL); (2) the time interval between the cessation of the interpolated learning and the recall of the OL. Differentiation is assumed to vary inversely with this interval.[13]

More specifically, it will be necessary to assume that the differentiation increases very slowly with the successive trials on the IL and that the function is a slowly rising positively accelerated one in contrast to the rapidly rising negatively accelerated function assumed to define the development of associative strength. Finally, it will be assumed that the strength of the tendency to respond with an IL word (and hence the amount of interference at recall) is a direct function of the associative strength of these responses and an inverse function of the strength or degree of differentiation between the two response systems.

With a small number of trials on the IL, differentiation or "knowing" the appropriateness of a "thought-of-response" to the set of recalling the OL would be very low and the subject would tend to give some responses from the IL. Up to a certain point, the greater the number of interpolated trials the greater would be the occurrence of these overt intrusions, for the associative strengths of the interpolated responses would be increasing relative to those of the OL. However, as the differentiation begins to develop it is assumed that the subject under the existing set to recall the OL will begin to recognize these interpolated responses as inappropriate and will attempt to inhibit them. As a consequence, the number of overt intrusions should drop off as the degree of differentiation increases, i.e., with a still greater number of trials on the IL.

Figure 6 shows the number of overt intrusions from the IL which appeared on the first recall trial of the OL in two experiments. The light circles represent the data from the present study (experiment B), while the dark circles indicate the same type of data from the earlier Thune and Underwood study.[14] It will be observed that the two studies present essentially the same intrusion data; the number of intrusions is greatest at about 10 interpolated trials from which point the frequency drops off rapidly, approaching zero by 20 to 25 trials. It will be recalled, however, that the total amount of RI does not decrease with the decrease in the number of overt intrusions. Thus, in the present experiment the amount of successful recall on the first relearning trial under the three degrees of interpolation was approximately equal despite the decrease in the number of intrusions with increased interpola-

[13] Phenomenologically this symbolic construct would appear to be related to the verbally reported experience of "knowing" on the part of the subject that the responses from the interpolated learning are inappropriate at the attempted recall of the OL. Degree of differentiation in this sense is thus an indication of the degree to which the subject identifies the list to which each response belongs.

[14] The conditions and techniques for the two experiments were very similar. In the Thune and Underwood study the degree of original learning was slightly less than in the present experiments.

tion. This same phenomenon was observed in the Thune and Underwood experiment.

The present explanation of the above phenomenon would be that the occurrence of the interpolated response in implicit form, and its rejection by the subject because it is recognized as wrong, i.e., differentiated, so decreases the anticipation time available for the original response that, even if the original response is available, the subject is not able to respond with it in time. There is thus produced one form of what may be referred to as *implicit* interference. With great overlearning of the IL, it is possible that the rejection time of these interpolated responses could be so decreased that although a reduction in RI is not observed at recall, the inhibition should show more rapid dissipation during the relearning. This was found in the present experiment with the highest degree of interpolation used and has been observed elsewhere (16).

Another form of interference resulting in failure or *blocking* of a response probably occurs because of the near equality of the competing response tendencies. Under such conditions the subject is often unable to choose between the two responses within the two-second period available for anticipation. Presumably such blocking would predominate when equal amounts of practice are given on the two lists and differentiation is low. In the present experiment this situation would be most closely approximated under the condition of eight interpolated trials. Near equality of the competing responses might also account for the partial intrusions as noted by Melton and Irwin (12) or, if the activity is such to allow it, a fusion of the two responses

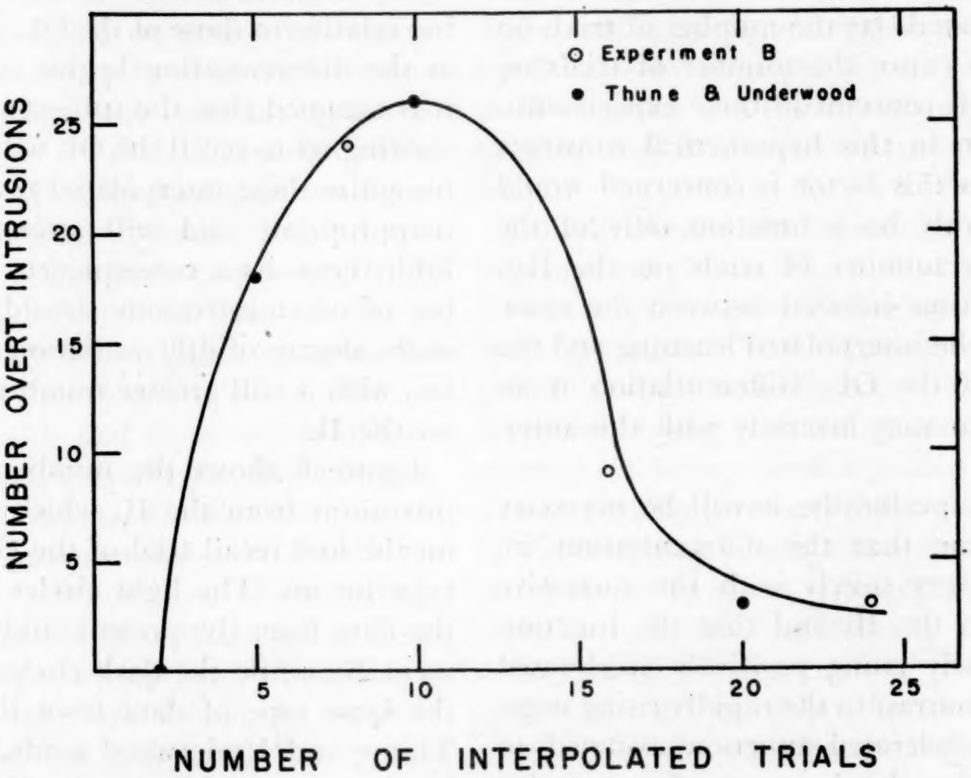

Fig. 6. Overt intrusions at recall as a function of the number of interpolated lists. The curve is a product of two experiments, Thune and Underwood (16) and experiment B. Ordinate values indicate the total number of intrusions which occurred on the first recall trial.

similar to that observed by Sears and Hovland (14).

Turning now to the variable of the time interval between the cessation of interpolated learning and recall of the OL, it will be seen that differentiation should be highest after a large number of interpolated trials. The subject would thus instruct himself on the recall trials not to give any responses from the list he had just learned (interpolated). Under such conditions, considerable inhibition might occur as a result of implicit interference although there would be but little overt interference. In the present experiment, increase in the number of interpolated trials and decrease in the time interval between interpolated learning and recall operate jointly to increase differentiation with the result that one should expect to find a greater amount of implicit interference with increase in the amount of interpolated learning.

The conditions of the present experiment makes it difficult to determine the relative weights which must be given to the two factors determining the degree of differentiation, i.e., the number of trials on interpolated learning and the time variable. However, the following analysis of the data provides some information as to the importance of the time interval. If pairs of original and interpolated responses which have had the same number of reinforcements (correct anticipations) in conditions IIb and IIIB (8 and 16 interpolated trials respectively) are selected, the conditions following the former will differ from the latter only in the length of the time interval between interpolated learning and recall. Considerable difficulty was encountered in finding sufficient cases for both conditions to make the results significant. It was necessary to combine several degrees of response-strength. For the OLs of condition IIb and IIIb, all cases which had from 0 to 4 reinforcements were selected, and for the ILs of these conditions, all cases that had from 1 to 7 reinforcements were chosen (providing, of course, these interpolated responses were paired with original responses that had from 0 to 4 reinforcements). On condition IIb there was a total of 202 such cases, but on condition IIIb there were only 55 cases. Of the 202 cases for condition IIb, 18 (9%) resulted in intrusions at recall. With the 55 cases of condition IIIb, *no* intrusions were recorded at recall. This would seem to suggest that the longer period between learning the IL and recall of the OL *does* result in an increase in the frequency of overt intrusions. Furthermore, the total cases of "no response" plus the 18 intrusions of condition IIb amount to 86 per cent of the 202 cases. On condition IIIb, there were 46 cases of "no response" at recall for a total of 84 per cent. Thus, while the actual inhibition produced in both cases was approximately the same, the amount of that inhibition that could be attributed to overt intrusions was greater in condition IIb than in IIIb. The time interval is apparently the only variable that could produce this difference.

In concluding this discussion of the results of experiment B, two tests of the theoretical interpretation offered will be suggested. Considerable emphasis has been placed on the role implicit intrusions play in determining the extent of RI. It has been suggested that with high degrees of interpolated learning, implicit interference accounts for the major share of the inhibition because of the limited rejection time of the "recognized" incorrect responses. An implication of this hypothesis would be that if an increased anticipation time were allowed at recall for all conditions of experiment B, a

greater decrease in inhibition would occur for IVb than for IIIb, and a greater decrease for IIIb than for IIb. Or, stated in more general terms, with high degrees of interpolation, an increase in the anticipation time of 2.0 seconds used here should result in a greater decrease in the amount of RI the greater the amount of interpolated learning.

Another test could be made of the postulate concerning the differentiation factor and its relation to implicit interference. Thus, if differentiation decreases over a period of time, an increase in the period between cessation of interpolation and recall should result in an increase in the number of overt intrusions, other conditions being equal, although the absolute RI should remain about the same. Either or both of these experiments would provide an empirical test of the more or less *ad hoc* theoretical conceptions inferred here on the basis of the present experimental facts.

B. INTERPRETATION OF EXPERIMENTS A AND C

Turning to the results of experiments A and C, in which the variable manipulated was the number of ILs and PLs and not the degree of learning of a single IL, a result should be noted first which in one respect parallels the findings of experiment B but which, in another respect, is quite the opposite. Thus, all three experiments agreed in finding a lack of relationship between variations in the amount of RI (or PI) and the number of overt intrusions at recall for the different conditions of interpolated learning. Experiments A and C differ from B, however, in that in the former the amount of RI and PI varied for the different experimental conditions (number of lists) while the number of overt intrusions remained approximately constant at the first recall trial, whereas in experiment B, RI remained constant under the different interpolated conditions and the number of overt intrusions varied.

It will be recalled that the decrease in the number of overt intrusions in experiment B was accounted for in terms of the increased degree of differentiation that was assumed to develop with greater number of trials on the ILs and the brief time interval between the end of this learning and the recall of the OL. This increased differentiation led to a reduction in overt intrusions and a greater number of implicit intrusions (presumably of the inhibition rather than blocking variety) occurred. In experiment A, however, there is no variation in the number of trials on the ILs, which, according to the hypothesis, leads to the implication that the degree of differentiation for the various conditions would not differ as in experiment B. Although the difference in time interval between the last IL and relearning would produce some variation in this hypothetical condition, it would presumably not be great.

Because of this relative unimportance of differentiation as heretofore defined, variation in the amount of RI in experiment A cannot be accounted for in terms of any great variation in overt and implicit intrusions. The most plausible interpretation would appear to be that the major factor responsible for the greater amount of RI with the larger number of ILs is the increased blocking of the original responses that results because of the greater number of competing response words associated with each stimulus word. Conditions for such blocking were optimal, for not only was differen-

tiation low, but approximately the same amounts of practice were given the OLs and ILs.

The minor role of the slight amount of variation in differentiation of the several ILs from the OL is revealed in the tendency for the number of overt intrusions from the ILs learned last to be relatively small. It is a possibility, then, that the degree of differentiation of the OL from the ILs is also a function of the degree of contiguity of their learning. Thus in the case of learning a number of lists, adjoining lists might, other things being equal, be more confused than more widely separated lists. Tending to support this interpretation is the finding of experiment C that the number of intrusions from lists 5 and 6 (those learned just before the list to be recalled) was greater than from earlier lists.

Considering further the results of experiment C it will be recalled that a brief discussion of the variables influencing PI was given in the first chapter. The influence of one of these variables is largely theoretical in nature and has been treated as such in the preceding discussion of RI. The variable in question is that of the temporal interval intervening between learning and recall. Since this variable is considered important in interpreting both RI and PI, it seems necessary at this point to review the logic leading to the assumption of its importance.

In the operations used to produce PI, the experimenter merely increases the temporal interval between any two arbitrarily chosen trials of a second list, the interval being in excess of the 6 to 8 seconds of the usual rote learning experiment. It is known that the associative inhibition during the learning of the second list is of small consequence after a few trials (10, 16). The subject could proceed with *continuous* learning of the second list to perfection without deleterious effects of the first list being manifest after the first few trials. However, if a rest interval is introduced during the learning of the second list, inhibition will result when learning is resumed. The inhibition as measured is called PI, and the evidence of overt intrusions leave little doubt that the first list is interfering with the recall of the second. It would seem patent that the time interval is all important as an experimental variable although no objective evidence is available on PI as a function of this interval. For this reason, the influence of the variable has a hypothetical status.

According to the interpretation considered here, the decrement occurring in the PI paradigm would be a consequence of the lower degree of differentiation of the OL from the PLs that would develop with the time interval between learning and recall. While this postulate would account satisfactorily for the phenomenon of PI itself, it is not adequate to explain the results of experiment C which show that PI varied as a function of the number of PLs. That is, the time interval between cessation of the learning of the OL and recall was constant for all three work conditions.

The most plausible explanation of this difference would again seem to be the greater number of competing responses which have been associated with the cue words. With the lowered degree of differentiation among the lists that would develop in the time interval between learning and recall in this experiment, the set to recall a word would operate less discriminately. The number of near equal and presumably conflicting re-

sponse tendencies would, of course, vary with the number of responses associated with each stimulus word.

Some reference should be made here to the differences obtaining in the RI and PI experiments. First of all, it is readily apparent that RI is considerably greater than PI and the inference is that there are fewer, or less strong, interfering tendencies at the recall point in the PI paradigm than in the RI paradigm. Previous interpretations of this difference have utilized the concept of unlearning (10, 13), and at present it seems the most adequate concept to employ for the present experiments. When dealing with competing tendencies of near equal objective strength (in terms of number or previous correct anticipations), unlearning appears to be an extremely useful concept.

Unlearning, it will be remembered, has been postulated as a weakening of the response tendencies of a first list by virtue of their non-reinforcement during the learning of a second list where certain similarity relationships prevail between the two lists (10, 13). The weakening may be conceived as permanent whatever its degree. Or, instead of a weakening, one might think of the change as the building up of avoidance responses for the first list, although such an interpretation has no advantage.

In considering the difference between PI and RI it has been suggested (13) that because of this weakening of the OL this list will be less likely to be recalled than a second learned list. Since the first list is recalled in the RI paradigm and the second in the PI, RI will be greater than PI. It should be pointed out, moreover, that unlearning has double action in producing the differences between PI and RI. In general, the weakening of the original list should *increase* the probabilities that the responses of a second learned list will interfere with the recall of the first (RI). By the same logic, the weakening of the first list should *decrease* the probabilities that it will interfere with the recall of the second (PI).

The difference in the rate of dissipation of RI and PI during relearning is contingent upon the same general interpretation. In experiment A, the OL has been unlearned and the last IL has not been unlearned. Consequently, during relearning, the last IL must be unlearned or weakened before the interference effects disappear. This is congruent with the hypothesis stated in the first chapter that the duration of the unlearning process is indicated by the extent of associative inhibition. In short, the fundamental basis for the two forms of inhibition is the same, but in one locus it is called associative inhibition and in the other, retroactive inhibition. In analyzing the PI paradigm, it will be noted that the situation is reversed. Not only has the list to be recalled never been weakened by unlearning, but there is no list to "unlearn" during the relearning process. This hypothesis, if accepted, will account for the transitoriness of PI in experiment C and the persistence of RI in experiment A.

Chapter V
Summary

EXPERIMENT A

Experiment A, on retroactive inhibition, was designed to discover the decremental effects on retention produced by the learning of 2, 4, and 6 interpolated lists. Paired two-syllable adjectives, 10 pairs to a list, made up the learning material. Twenty-four subjects went through four experimental conditions in counterbalanced order after previously serving two practice sessions. The original learning was carried to a criterion of six or more correct responses, after which the subjects (1) rested 25 minutes, (2) learned 2 interpolated lists, (3) learned 4 interpolated lists, or (4) learned 6 interpolated lists. After rest and/or interpolation the subjects relearned the original list to a criterion of two successive errorless trials. Each interpolated list was presented for four trials, and each of these lists had the same stimulus word as the original list although they were paired with different responses.

The results showed:

1. Retroactive inhibition increased directly with an increase in the number of interpolated lists. With six interpolated lists, forgetting, as measured by recall scores, was almost complete.

2. No reliable inhibition was evident in the number of trials required to relearn the original list to mastery.

3. The frequency of overt intrusions from the interpolated lists during the recall and the relearning of the original list was relatively constant regardless of the number of interpolated lists.

EXPERIMENT B

Experiment B, also on retroactive inhibition, served as a control for experiment A. Instead of learning 2, 4, and 6 interpolated lists for four trials each, the subjects learned a single interpolated list for 8, 16, and 24 trials. Thus, although the number of interpolated trials was constant in both experiments, the number of lists learned in those trials varied. All other conditions were constant between the two experiments.

The results showed:

1. Retroactive inhibition remained relatively constant on the first recall trial whether there were 8, 16, or 24 trials on the interpolated list. The rate of recovery from the inhibition varied, however, with the most rapid dissipation evident after 24 interpolated trials, and the greatest perseveration after 16 trials.

2. Only one condition, that one with 16 interpolated trials, showed reliable inhibition in the number of trials required to relearn the original list to mastery.

3. The frequency of overt intrusions during the recall and relearning of the original list consistently decreased as the number of interpolated trials increased.

EXPERIMENT C

Experiment C, on proactive inhibition, was the direct counterpart of experiment A. Instead of learning 2, 4, and 6 lists after the original learning, these lists were learned before the original learning. In both experiments, the recall of the original list took place after 25 minutes.

The results showed:

1. Proactive inhibition increased directly as the number of prior lists increased. However, the amount of decrement in retention produced by the prior lists was less than that produced by

interpolated lists, i.e., proactive inhibition was less than retroactive inhibition.

2. Proactive inhibition was very transitory, being evident only on the first recall trial.

3. The number of overt intrusions from the prior lists during the recall and relearning of the original list was relatively constant although smaller in number than in experiment A.

Theoretically, the present experiments have been concerned with the two-factor theory of retroactive inhibition. It has been pointed out that although the original formulation of the unlearning theory may have been based on questionable assumptions, the principle of unlearning appears to be essentially sound. Experiments A and C of the present series were designed to test an implication of an hypothesis as to the more exact nature of the unlearning process. The hypothesis identifies the temporal duration of unlearning with the duration of associative inhibition in the learning of interpolated lists or list. Since associative inhibition is usually quite transitory during the learning of a second list (1 to 5 trials), it was argued that the unlearning of the first list must then be nearly complete at the point where evidence for associative inhibition is no longer available. It has also been shown that retroactive inhibition should be greater than proactive inhibition, since the former is influenced by unlearning and the latter is not. If then, unlearning takes place for only a "few" trials (as long as associative inhibition is evident) during the learning of the second list, the differences between retroactive and proactive inhibition should be constant for all corresponding degrees of interpolated and prior learning, provided at least a "few" trials are given in the lowest degree of interpolated or prior learning used. Experiments A and C were a test of this implication of the hypothesis about the extent of unlearning. The hypothesis received substantiation since it was found that the differences between retroactive and proactive inhibition at recall were relatively constant for 2, 4, and 6 interpolated and prior lists.

A fairly complete theoretical interpretation has been given for the results of experiment B. The results of experiments A and C are thought to be of a more complex character than those for experiment B and only an incomplete interpretation has been attempted.

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